

CLASSIFICATION AND ORDINATION OF ALPINE PLANT COMMUNITIES, SHEEP MOUNTAIN, LEMHI COUNTY, IDAHO

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ABSTRACT

The alpine vegetation in the immediate vicinity of Sheep Mountain, Lemhi Range, Lemhi County, Idaho, was investigated using data from field observations analyzed by the programs TWINSPLAN and CANOCO (CCA). Percent cover of vegetation and environmental data were recorded for 77 plots. Eight communities were identified and described with respect to apparent habitat preferences. The most frequent communities are characterized by a) *Carex rupestris*, b) *Carex elynoides*, and c) *Calamagrostis purpurascens*–*Carex elynoides*. An exposure gradient showed the strongest correlation with the community distribution, but substrate, elevation, and slope were also found to be important. In general, the study area communities present a uniformly dry turf-like physiognomy, with some early snowbed and *Dryas* or *Salix* mat communities occasionally present.

In the last few decades, many alpine studies have been published, but of all the alpine areas in North America, Idaho alpine has received the least attention. Until recently, it was not common knowledge that Idaho has well-developed alpine communities, but this and other studies document its existence. Our observations are supported by numerous collections and studies of several researchers dating back to the 1800's. Thomas Nuttall may have made alpine collections in Idaho as early as 1834 (Mckelvey 1955), followed by L. F. Henderson (1890's), Hitchcock and Muhlick, and Davis (1940's and '50's) (Henderson 1992). The second author and students associated with the University of Idaho Herbarium have been collecting in and studying the east-central Idaho alpine since 1973. Brunsfeld (1981) completed an alpine flora for part of east-central Idaho based on collections from the Lost River and southern Lemhi ranges, and the southern Beaverhead Mountains. Caicco (1983) and Moseley (1985) have each completed community studies for selected sites in east-central Idaho.

From these collections and studies, as well as from field observations of the second author, Idaho alpine appears to be restricted to the mountains of central and east-central Idaho. The present research area, Sheep Mountain, is located in the southern Lemhi

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Range, about 32 km south of Leadore. The Sheep Mountain alpine is in excellent condition, and the site has been accepted as a candidate Research Natural Area by the U.S. Forest Service.

Other Idaho alpine studies (Caicco 1983; Moseley 1985) have documented all of the general categories of alpine communities typically seen in temperate alpine locations, e.g., fellfield, turf, meadow, and bog. Based on those studies, field observations by the second author, and the topographic and substrate variety of Sheep Mountain, we predicted that Sheep Mountain would also have a wide variety of alpine communities, some possibly unique. To test this prediction, we sampled the Sheep Mountain alpine vegetation with the goals of classifying the plant communities, describing their distribution with respect to measured environmental variables, and relating the results of the analysis to several regional studies.

STUDY AREA

The proposed Sheep Mountain Research Natural Area (RNA) (44°22'N, 113°16'W) (Fig. 1) is centered along the crest of the south-east trending Lemhi Range, and encompasses 3.2 km of ridgeline. Elevation of the RNA ranges from 3000 to 3312 m, includes approximately 220 ha, and, except for scattered individuals of *Pinus albicaulis* Engelm. in a few locations to 3025 m, the area is dominated by alpine vegetation. Sixty-six of the 77 plots sampled were located in the RNA; the other 11 were placed 0.8 km to the south on the north slope of Spring Mountain (Fig. 1). Timberline in both locations is composed of *Pinus albicaulis* and *Juniperis communis* L. associated with *Festuca ovina* L. var. *ingrata* Hackel ex Beal and *Artemisia tridentata* Nutt. Access is provided by primitive roads originating in Squaw Creek Canyon on the west side and Spring Mountain Canyon on the east.

Two parent materials, dolomite and quartzite (Ruppel and Lopez 1981), are exposed within alpine habitats with abrupt transitions between each parent material. Most of the soil is derived from dolomite, except for a few isolated bands where the parent material is quartzite.

Climatic data were estimated from regional weather stations (Myron Molnau, Office of State Climatologist, personal communication). Temperature information originates from Leadore, Idaho, elevation 1829 m, 32 km north, and was corrected for elevation (0.64°C/100 m). The coldest month is January with an average temperature of -16° C, while the warmest month is July at 9°C. Precipitation for the study area is assumed to be similar to Meadow Lake, 6.4 km to the north; total precipitation for the year is 853 mm; a unimodal pattern is evident, with the majority of moisture falling during the winter months, 110 mm in January alone. The summer months are

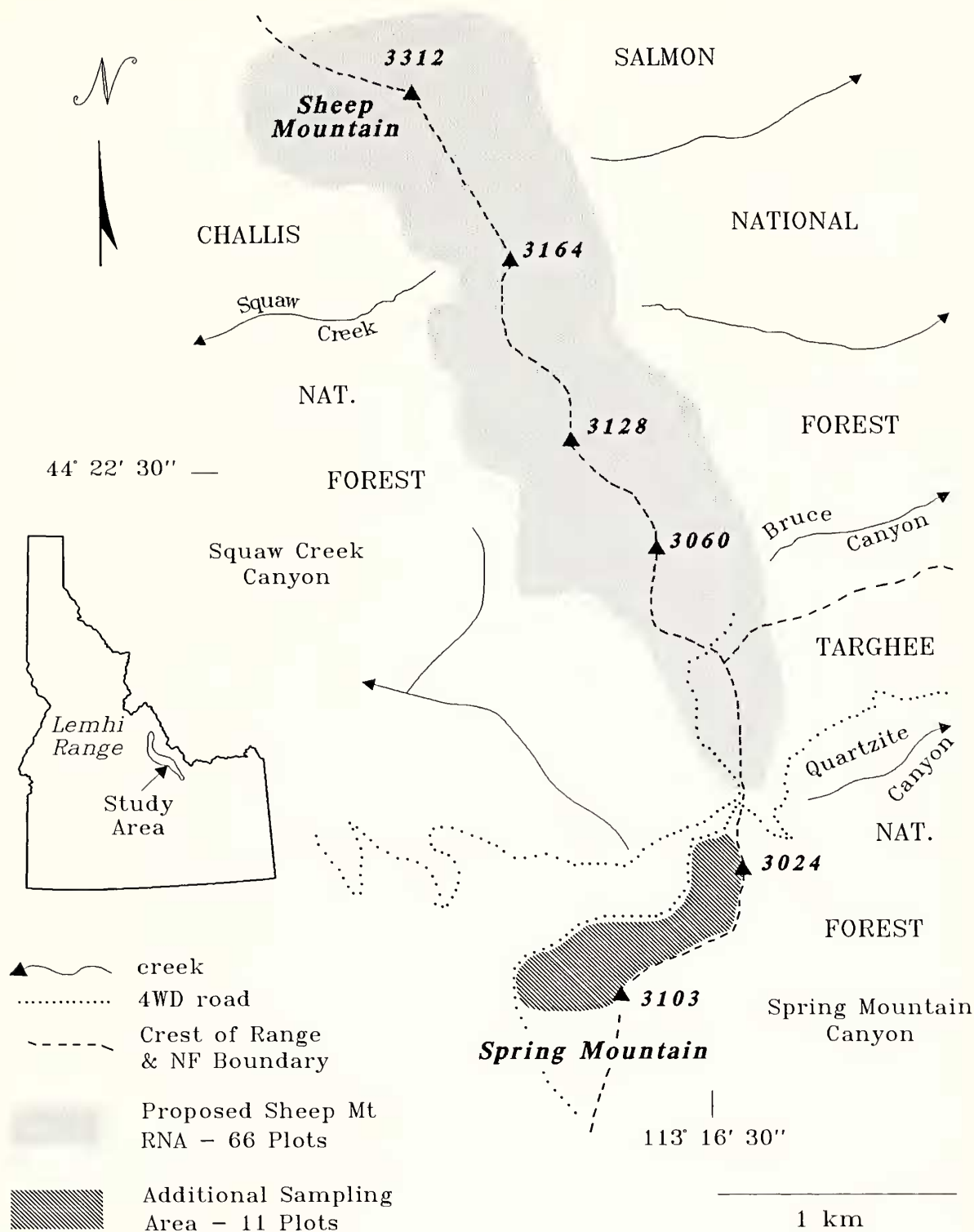


FIG. 1. Study area location. Elevations are shown in meters.

generally dry, with only 27 mm falling in July as occasional rain-showers. Overall, the area has a mountain climate with both coastal and continental influences and prevailing winds from the west (Ross and Savage 1967) resulting in cold, wet winters, and warm, dry summers. All vegetation sampled was clear of snow by 21 June 1992 when sampling began, although lingering snowbanks were present in places.

Land use history includes mostly mining exploration, with apparently little grazing. The remains of several small mines or pits are evident, but they only insignificantly scar the area. Due to the lack of perennial moisture in the alpine, grazing has historically been insignificant; none has occurred in the past twenty years (Steve Spencer, Range Management, Lost River Range District, personal communication).

METHODS

Data collection. Fieldwork was conducted from 21 June to 25 July 1992. These dates represent the earliest opportunity to do fieldwork, to the latest, initially due to lingering snow, and then drought conditions. Only vegetation above treeline and krummholz was examined. Seventy-seven plots were sampled using the methods of Bliss (1963) and Douglas and Bliss (1977). The process begins with the identification of a homogeneous stand of alpine plants no less than 60 m² in size. All distinctively different homogeneous stands in the study area were sampled. Additionally, when size of the stand permitted, plots were arranged so as to best represent the diversity of slopes, positions on slopes, and aspects present in the stand. Within the stand a plot 4 by 8 m is measured and then further divided into eight rows, each 4 by 1 m. Replicate plots are sampled if permitted by the size of the stand. Four of the rows are randomly selected to be sampled by five quadrats, each 0.2 by 0.5 m and spaced at 0.5 m intervals. If an odd row is selected, the first quadrat is placed adjacent to the edge of the plot; whereas in an even row, the first quadrat is displaced 0.5 m. The end result is 20 quadrats with a combined area of 2 m². For each quadrat, the percent cover for all of the species was estimated visually using a quadrat constructed as described in Daubenmire (1959). The plot percent cover for a species was the average for the 20 quadrats.

Environmental data were recorded for each plot including location, elevation, slope, substrate, and exposure index. Elevation was calculated from a United States Geological Survey 7.5' topographic map of either the Gilmore or Big Windy Peak Quadrangle. Plot substrate was identified by rock samples examined by William Rember (Department of Geology, University of Idaho). The exposure index consisted of a scale from 1 to 5, 1 being a low exposure, and reflected several environmental factors at once (del Moral 1979). The factors considered were slope and aspect (measured by Brunton Pocket Transit), position on ridge, substrate, soil development, soil consistency, and snow/drainage patterns.

Voucher specimens were deposited in the University of Idaho Herbarium (ID). Nomenclature follows Hitchcock and Cronquist (1973) except for the Poaceae (Welsh et al. 1987), and *Cymopterus*

TABLE 1. LIST OF PLANTS USED IN TWINSPAN AND CCA ANALYSES AND ASSOCIATED ABBREVIATIONS DISPLAYED IN GROUP COMPOSITION TABLE (TABLE 1), DENDROGRAM (FIG. 2) AND SPECIES ORDINATION DIAGRAM (FIG. 4). All species were present in at least one plot at greater than 2% cover.

Species	Abbreviations
<i>Achillea millefolium</i> L. var. <i>alpicola</i> (Rydb.) Garrett	Ach mil
<i>Agoseris glauca</i> (Pursh) Raf. var. <i>dasycephala</i> (T. & G.) Jeps.	Ago gla
<i>Anemone multifida</i> Poir. var. <i>tetonensis</i> (Porter) Hitchc.	Ane mul
<i>Antennaria lanata</i> (Hook.) Greene	Ant lan
<i>Antennaria umbrinella</i> Rydb.	Ant umb
<i>Arenaria congesta</i> Nutt. var. <i>cephaloidea</i> (Rydb.) McGuire	Are con
<i>Arenaria obtusiloba</i> (Rydb.) Fern.	Are obt
<i>Astragalus kentrophyta</i> Gray var. <i>implexus</i> (Canby) Barneby	Ast ken
<i>Calamagrostis purpurascens</i> R. Br.	Cal pur
<i>Carex elynoides</i> Holm.	Car ely
<i>Carex rupestris</i> All.	Car rup
<i>Cymopterus douglassii</i> R. L. Hartman et Constance	Cym dou
<i>Cymopterus nivalis</i> Wats.	Cym niv
<i>Dryas octopetala</i> L. var. <i>hookeriana</i> (Juz.) Breit	Dry oct
<i>Elymus spicatus</i> (Pursh) Gould	Ely spi
<i>Elymus trachycaulus</i> (Link) Gould ex Shinnery	Ely tra
<i>Erigeron compositus</i> Pursh var. <i>glabratus</i> Macoun	Eri com
<i>Eritrichium nanum</i> (Vill.) Schrad. var. <i>elongatum</i> (Rydb.) Cronq.	Eri nan
<i>Festuca ovina</i> L. var. <i>brevifolia</i> (R. Br.) Wats.	Fes ovi
<i>Frasera speciosa</i> Dougl.	Fra spe
<i>Haplopappus acaulis</i> (Nutt.) Gray	Hap aca
<i>Hymenoxys grandiflora</i> (T. & G.) Parker	Hym gra
<i>Leucopoa kingii</i> (S. Wats.) Weber	Leu kin
<i>Lloydia serotina</i> (L.) Sweet.	Llo ser
<i>Lupinus argenteus</i> Pursh var. <i>depressus</i> (Rydb.) Hitchc.	Lup arg
<i>Oxytropis besseyii</i> (Rydb.) Blank. var. <i>argophylla</i> (Rydb.) Barneby	Oxy bes
<i>Penstemon attenuatus</i> Dougl. var. <i>pseudoprocerus</i> (Rydb.) Cronq.	Pen att
<i>Phlox multiflora</i> A. Nels.	Phl mul
<i>Phlox pulvinata</i> (Wherry) Cronq.	Phl pul
<i>Potentilla diversifolia</i> Lehm.	Pot div
<i>Potentilla ovina</i> Macoun	Pot ovi
<i>Salix nivalis</i> Hook. var. <i>nivalis</i>	Sal niv
<i>Selaginella densa</i> Rydb.	Sel den
<i>Silene repens</i> Pers.	Sil rep
<i>Solidago multiradiata</i> Ait. var. <i>scopulorum</i> Gray	Sol mul
<i>Synthyris pinnatifida</i> Wats. var. <i>canescens</i> (Pennell) Cronq.	Syn pin
<i>Trifolium haydenii</i> Porter	Tri hay
<i>Zigadenus elegans</i> Pursh	Zig ele

douglassii R. L. Hartman et Constance (Hartman and Constance 1985).

Data analysis. To simplify the data analysis, only plants with greater than 2% cover in a particular plot were considered for analysis; in all, 38 species were included (Tables 1 and 2). This simplification is justified because rare species (here defined as having less than 2% mean coverage in a plot) carry an insignificant portion of

TABLE 2. GROUP COMPOSITION TABLE. Group composition with only the 38 species used in the data analysis included. Species abbreviations are explained in Table 1. The eight groups are as follows: (G1) *Salix nivalis*, (G2) *Solidago multiradiata-Trifolium haydenii*, (G3) *Carex elynoides-Trifolium haydenii*, (G4) *Carex elynoides*, (G5) *Calamagrostis purpurascens-Carex elynoides*, (G6) *Carex rupestris*, (G7) *Dryas octopetala*, and (G8) *Leucopoa kingii*. Mean percent cover (C) and frequency of presence in stands (F) are listed for each species. Cover less than 0.5% is indicated by a P.

	G1			G2			G3			G4			G5			G6			G7			G8		
	C	F		C	F		C	F		C	F		C	F		C	F		C	F		C	F	
Ach mil				1	100		P	20		P	25		P	7								3	50	
Ago gla				P	50		P			P	6										P	100		
Ane mul				P	50					P	6		P	7										
Ant lan							P	20		1	31		P	7										
Ant umb	1	100					1			1	69		P	37		P	35				P		17	
Are con				2	100		P	40		1	38		P	4										
Are obt							1	80		P	69		2	100		1	82		1	100	P		33	
Ast ken	3	100					P			P	13		1	44		P	12		3	100	P		33	
Cal pur							1	60		2	25		14	100		3	94							
Car ely	15	100					36	100		29	100		14	100		1	35					12	83	
Car rup							5	60		1	19		8	85		16	100		7	100	P		17	
Cym dou													P	7		2	76							
Cym niv										1	38		P	22		1	24				2		83	
Dry oct																			45	100				

TABLE 2. CONTINUED.

	G1		G2		G3		G4		G5		G6		G7		G8	
	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Ely spi			P	50			2	31			1	6			P	33
Ely tra					P	6										
Eri com					P	13			P	11	P	6			P	67
Eri nan					P	13			2	78	1	82			P	33
Fes ovi			1	100		20	5	44								
Fra spe			3	100		20			P	7						
Hap aca					P			19	P	4	P	12				
Hym gra					P	60		25	2	96	1	53			P	33
Leu kin					P	20	2	44	P	7	P	6			19	100
Llo ser	2	100	2	100	P	40			P	7	P	6		50	P	17
Lup arg			2	100			2	50	P	7				100	4	100
Oxy bes					P			25	1	85	1	82			P	17
Pen att					P			25							P	33
Phl mul							1	50								
Phl pul	3	100	4	100		100	5	81		100	4	94		1	5	100
Pot div	3	100	1	50		80	1	19	P	4					P	17
Pot ovi						20	1	81	1	82					P	33
Sal niv	32	100												2	50	
Sel den					1		1	31	1	41					1	33
Sil rep					P			6							2	67
Sol mul	7	100	21	100	P	80		19	P	7				P	100	
Syn pin	1	50			P	100		63	P	15				P	100	67
Tri hay			17	100		100			P	7		6				
Soil	30		39		41				43		65			35	49	

TWINSPAN is a divisive hierarchical classification program using reciprocal averaging repeatedly to divide the data set into smaller and smaller groups (Hill 1979). Analysis was accomplished with the default species cut levels of 0, 2, 5, 10, and 20 percent groupings. The resulting dendrogram was interpreted with respect to field observations and measured environmental variables, with described groups being derived from several levels in the hierarchy.

CCA uses reciprocal averaging constrained by environmental information (ter Braak 1987) to produce axes that are linear combinations of the measured environmental factors. CCA is a kind of reciprocal averaging transformed from an indirect to a direct gradient analysis. An eigenvalue (λ) for each axis indicates the variation of the species data explained by that axis; the larger the eigenvalue, the larger the dispersion of species scores along the axis. When plotted, species scores are derived from the weighted averages of site scores. Arrows in the ordination diagram represent the direction of variation of an environmental variable. The mean of an environmental variable is represented by the origin, so that the direction that the arrowhead points is above average and the opposite direction is below average. The length of the arrow indicates how well the environmental variable is correlated with the pattern in the ordination diagram. Nominal variables or classes (e.g., substrate) are represented as points and are positioned so as to be the weighted average of the site scores of the sites belonging to that class. Each environmental variable also has a correlation coefficient (r) for each axis, which numerically indicates how well that environmental variable helps explain the observed variation on the axis. Overall variation explained by the illustrated ordination is determined by adding the eigenvalues for the axes and dividing by the total of the constrained eigenvalues. Sites perpendicularly projected onto the arrows provide a rank ordering of the sites for that environmental variable. Species are treated in the same manner, except the rank ordering is of the weighted averages of site environmental values of sites containing that species.

RESULTS

TWINSPAN analysis (Fig. 2) of the data set suggests eight groupings: 1) *Salix nivalis*, 2) *Solidago multiradiata*–*Trifolium haydenii*, 3) *Carex elynoides*–*Trifolium haydenii*, 4) *Carex elynoides*, 5) *Calamagrostis purpurascens*–*Carex elynoides*, 6) *Carex rupestris*, 7) *Dryas octopetala*, and 8) *Leucopoa kingii*. The first division ($\lambda = 0.492$) separates the *Leucopoa kingii* communities (Group 8) from the rest. The second division ($\lambda = 0.471$) primarily distinguishes the more exposed, drier, or steeper sites (Groups 5, 6, and 7) from the more mesic, sheltered sites (Groups 1, 2, 3, and 4). Group 7, *Dryas oc-*

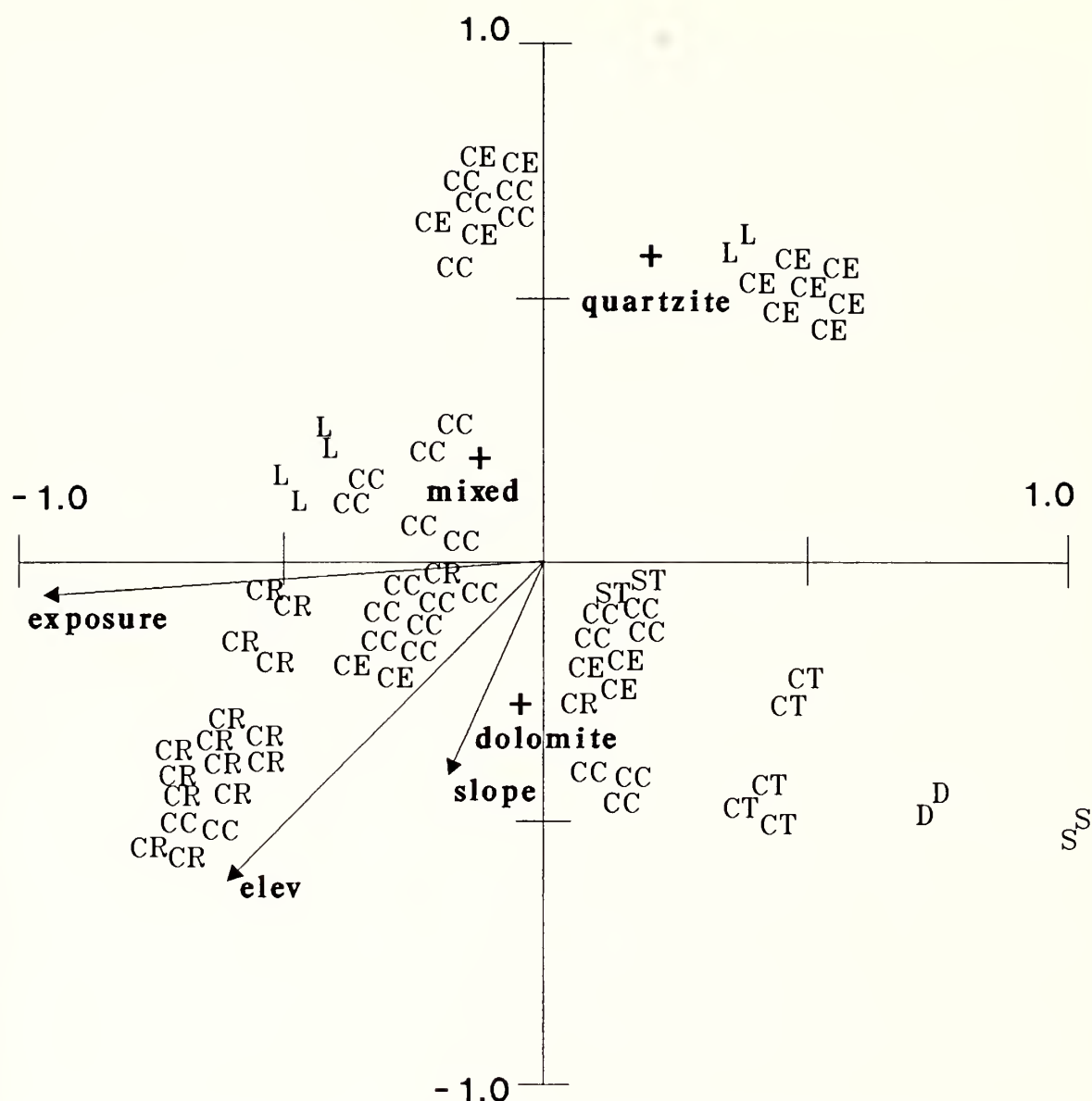


FIG. 3. CCA ordination of plots. Letters represent community membership. (S) *Salix nivalis*, (ST) *Solidago multiradiata*–*Trifolium haydenii*, (CT) *Carex elynoides*–*Trifolium haydenii*, (CE) *Carex elynoides*, (CC) *Calamagrostis purpurascens*–*Carex elynoides*, (CR) *Carex rupestris*, (D) *Dryas octopetala*, (L) *Leucopoa kingii*.

topetala, is identified as unique at Division 4 by not only having a high composition of *Dryas octopetala*, but also being the only group in which it was found. Division 6 separates the *Calamagrostis purpurascens*–*Carex elynoides* and *Carex rupestris* communities, but only with the smallest eigenvalue ($\lambda = 0.340$) in the dendrogram. Both communities were in exposed, dry locations and had many species in common, most noticeably, *Carex rupestris*. Division 3 ($\lambda = 0.527$) is again along an exposure gradient, with the *Carex elynoides* turf community (Group 4) being separated from the less exposed, winter snow-covered or early snowbed communities (Groups 1, 2, and 3). Additional divisions of the latter (Division 5, $\lambda = 0.593$; Division 7, $\lambda = 0.501$) appear to be associated with date

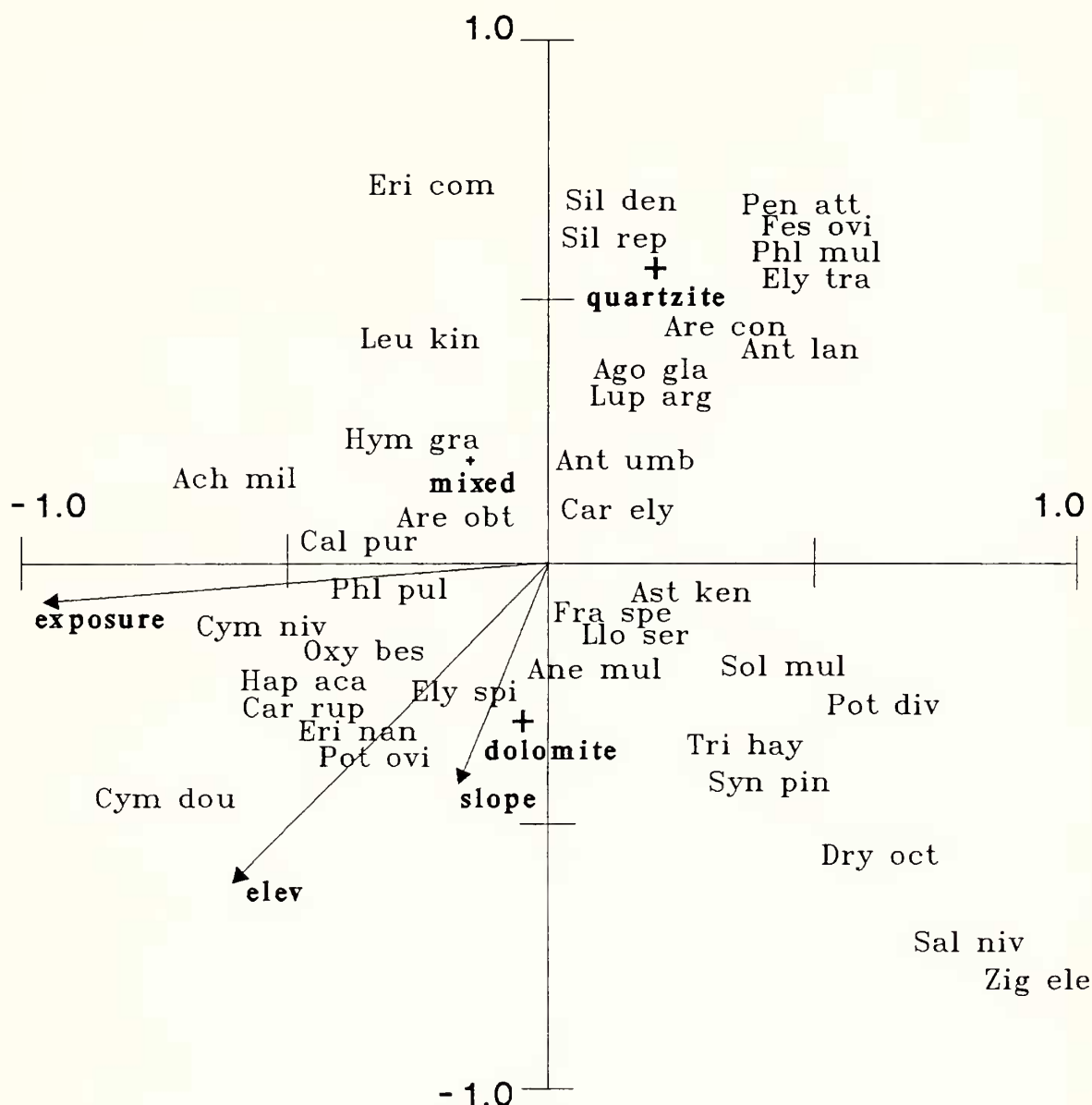


FIG. 4. CCA ordination of species. Species abbreviations are explained in Table 1.

of snowmelt, the *Carex elynoides*–*Trifolium haydenii* community (Group 3) being free of snow first, followed by the other two (Groups 1 and 2). The *Solidago multiradiata*–*Trifolium haydenii* community (Group 2) was in an obvious snow-collecting depression, but was free of snow by 21 June. The *Salix nivalis* community (Group 1) was also snow-free, but was fed by an adjacent snowbank.

The CCA ordinations for plots and species are depicted in Figures 3 and 4. The first axis ($\lambda = 0.45$) was correlated primarily with the exposure index ($r = -0.98$), but also partially with elevation ($r = -0.56$). The second axis ($\lambda = 0.30$) was correlated with substrate and elevation ($r = -0.58$). The third axis ($\lambda = 0.22$) was correlated only with slope ($r = 0.92$). Overall, the species and plot ordination diagrams, utilizing the first two axes, display 62.5% of the total variation in all the axes of the CCA ordination (total constrained $\lambda = 1.20$).

The plot ordination has the *Salix nivalis* community located in the least exposed, right position, while the *Carex rupestris* community occupies the exposed, left side of the diagram. In between are the remaining communities, which are further differentiated by substrate and elevation. The environmental variables failed to distinguish between two communities, *Carex elynoides* and *Calamagrostis purpurascens*–*Carex elynoides*, from each other; both communities are concentrated in the middle of the plot and span both substrates. The rest of the communities are well distinguished and will be discussed in detail.

The species ordination also reflects the dominant exposure gradient. *Zigadenus elegans* and *Salix nivalis* var. *nivalis* occupy the extreme right, least exposed position and *Cymopterus douglassii*, *Achillea millefolium* var. *alpicola*, and *Cymopterus nivalis* occupy the left. The elevation arrow shows *Cymopterus douglassii*, a regional endemic, to be the highest elevation plant collected, while at the opposite extreme is a collection of many species, the most abundant being *Selaginella densa* and *Festuca ovina* var. *brevifolia*. Only *Selaginella densa*, *Erigeron compositus* var. *glabratus*, *Penstemon attenuatus* var. *pseudoprocerus*, *Festuca ovina* var. *brevifolia*, *Phlox multiflora*, and *Elymus trachycaulus* were collected solely on quartzite. The rest of the species were collected on dolomite or both quartzite and dolomite substrates.

DISCUSSION

Group 1: Salix nivalis (N = 2). This community was located on a shelf (slope = 11°) at the base of a steep ridge, and was clearly associated with persistent snowbanks, drainage from which kept the soil waterlogged during the majority of the growing season (exposure index = 1). Vegetation cover was high (70%) with *Salix nivalis* at 32% ground cover. The location was well-protected from the prevailing westerly winds due to a north-northeast aspect (elevation 3024 m). Soil development was moderate on a dolomite substrate. Other important species present were *Carex elynoides* (15%), *Solidago multiradiata* var. *scopulorum* (7%), *Zigadenus elegans* (4%), *Potentilla diversifolia* (3%), and *Astragalus kentrophyta* var. *implexus* (3%).

From the CCA analysis, the *Salix nivalis* group is the least exposed, wettest community sampled. It has two species, *Salix nivalis* and *Zigadenus elegans*, that occupy the same low exposure position in the species ordination, but the community also contains some species, especially *Carex elynoides*, with more general distributions. This community, and the *Dryas octopetala* community, were the only ones associated with snowbanks still persisting at the time of

sampling. The TWINSpan divisions (Fig. 2) distinguishing Group 1 from the other mesic sites had high eigenvalues, especially Division 5 ($\lambda = 0.593$), highlighting the uniqueness of this community. Group 1 is also characterized by the near absence of the ubiquitous *Phlox pulvinata*, again revealing the extreme mesic nature of the group as compared to the rest of the study area.

Regional studies show *Salix nivalis* communities to be common in east-central Idaho (Brunsfield 1981), but replaced by *Salix arctica* in the Pioneer Mountains at the western edge of east-central Idaho (Caicco 1983). Brunsfield's observations support our description of this group as having a mesic habitat preference and occurring in dense mats wherever there is abundant, persistent water. *Salix nivalis* is not mentioned by Moseley (1985), but he was specifically examining *Leucopoa kingii* distributions and discusses other communities only if closely associated with *Leucopoa kingii*.

Group 2: Solidago multiradiata–Trifolium haydenii (N = 2). This community was observed in a snow-collecting depression (slope = 3°) on a northwest aspect at 2999 m. Vegetation cover was 61%, with *Solidago multiradiata* var. *scopulorum* at 21% and *Trifolium haydenii* at 17%. The sites were snow-free prior to sampling, and no additional drainage from other snowbanks was evident; the plots were scored a 3 on the moisture index, reflecting average exposure conditions. The soil was moderately developed from a dolomite substrate. Other important species present were *Phlox pulvinata* (4%) and *Frasera speciosa* (3%).

In the TWINSpan dendrogram (Fig. 2), Group 2 initially branches with Group 3, *Carex elynoides–Trifolium haydenii*, but is separated from Group 3 at Division 7 ($\lambda = 0.501$), due mostly to the conspicuous absence of *Carex elynoides*. These two groups were adjacent, and *Carex elynoides* was locally common in the areas around both groups. The absence of *Carex elynoides* suggests an abrupt environmental change, and it is suspected, but not observed, that this is due to a later date of snowmelt in Group 2. Group 3 is more mesic, but this results more from patterns of snowmelt drainage than from snow accumulation.

In the CCA plot diagram (Fig. 3), Group 2 occurs near the centroid for all environmental variables. *Solidago multiradiata* and *Trifolium haydenii* are in the lower right quadrant in the species ordination (Fig. 4), indicating a preference for low exposure, dolomite substrates, and average study area elevations.

Brunsfield (1981) found *Solidago multiradiata* on rocky, wet soils, and Caicco (1983) discusses a *Deschampsia cespitosa* (L.) Beauv. grassland in which *Solidago multiradiata* occurs with moderate abundance, but no mention is made of a community as described above. *Trifolium haydenii* is a regional endemic known only from southwestern Montana and adjacent Wyoming until recently dis-

covered in east-central Idaho; it occupies a variety of forest and alpine habitats (Henderson 1978).

Group 3: Carex elynoides–Trifolium haydenii (N = 5). This community occupies a north-northwest, relatively steep slope (24°) on dolomite, at an elevation of 3018 to 3060 m. At 80% vegetation coverage, it had the most cover of any group. *Carex elynoides* was present at 36% cover, and *Trifolium haydenii* had 23% coverage. Snow, although not present during sampling, appears to accumulate in large amounts both above and below the community, while the community itself is covered, but not deeply so, in winter. The well-developed soil was wet during sampling; many solifluction terraces were observed. The snow drainage pattern, the high vegetation cover, and the northerly aspect resulted in a score of 2 on the exposure index, indicating a greater than average moisture condition. Other important species were *Phlox pulvinata* (7%) and *Synthyris pinnatifida* var. *canescens* (3%).

The community is positioned in the lower right quadrant of the CCA plot ordination (Fig. 3), indicating low exposure, medium altitude, and a dolomite substrate. The species ordination (Fig. 4) shows *Trifolium haydenii* as preferential to the mesic sites, while *Carex elynoides* has a more general habitat requirement, occurring in all but the driest, most exposed sites.

Other Idaho studies have described *Carex elynoides* as occasional to common, but never in association with *Trifolium haydenii*, a regional endemic (Brunsfeld 1981; Caicco 1983; Moseley 1985).

Group 4: Carex elynoides (N = 16). *Carex elynoides* turf is abundant in the study area. This community occurred on all aspects and on both dolomite and quartzite substrates. The sampling elevation was 3005 to 3054 m, and the mean slope and exposure index were 8.5° and 2.6, respectively. *Carex elynoides* by far dominated the community with 29% coverage, total vegetation coverage being 59%. *Phlox pulvinata* and *Agoseris glauca* were also important components with 5% and 2%, respectively.

Habitat preference, as revealed in the plot ordination (Fig. 3), tended toward the exposure centroid, but with wide dispersion in substrate and elevation. This community was found in areas not directly exposed to winter winds, with some snow accumulation, moderate slope, and a well-developed soil. The species ordination reveals *Carex elynoides* as a generalist, being located near the centroid. Previous Idaho studies have identified *Carex elynoides* communities as occasional to common, with a habitat preference similar to the above description (Brunsfeld 1981; Caicco, 1983; Moseley, 1985).

A phase of the *Carex elynoides* turf was highlighted by the TWINSPAN analysis (Fig. 2) when a small group of five plots was further delimited ($\lambda = 0.525$) with *Festuca ovina* var. *brevifolia* as the in-

indicator species. These plots were sampled in depressions or drainage areas and suggests a higher moisture phase of the *Carex elynoides* turf (exposure index = 2), with *Festuca ovina* var. *brevifolia* locally abundant (cover = 16%). *Festuca ovina* is a common species in the alpine of east-central Idaho, but was limited to this community in the study area. Neither Caicco (1983) nor Moseley (1985) mention this phase of a *Carex elynoides* community.

Group 5: Calamagrostis purpurascens–Carex elynoides (N = 27). This community was the largest in total number of plots and total area, and was found on westerly aspects, with an average slope of 12° and elevations from 3005 to 3133 m. The habitat is generally more exposed (average exposure index = 3.4) than *Carex elynoides* turf with *Calamagrostis purpurascens* and *Carex elynoides* each accounting for 14% of the total 57% vegetation coverage. Both dolomite and quartzite substrates are represented, but dolomite predominates. Other important plants were *Carex rupestris* (8%), *Phlox pulvinata* (7%), *Arenaria obtusiloba* (2%), and *Hymenoxys grandiflora* (2%).

In the TWINSPLAN analysis (Fig. 2), this group separated early from the other two *Carex elynoides* communities (Division 2, $\lambda = 0.471$). It is distinctive because of the large component of *Calamagrostis purpurascens*, as well as *Carex rupestris*, *Arenaria obtusiloba*, and *Hymenoxys grandiflora*, all four nearly restricted to this community. The CCA plot ordination (Fig. 3) has Group 5 positioned near the centroid for exposure, but widely dispersed relative to the other environmental factors. The environmental variables measured do not distinguish between Groups 4 and 5, but field observations suggest that *Calamagrostis purpurascens–Carex elynoides* plots occurred in the more exposed, drier sites. In fact, on one ridge in the study area, a *Calamagrostis purpurascens–Carex elynoides* community dominated the exposed northwest aspect, while a *Carex elynoides* community was restricted to the partially protected southeast aspect. At its upper boundaries, Group 5 grades into a *Carex rupestris* community (Group 6), which dominates dry, exposed ridgetops. *Calamagrostis purpurascens* is located near the centroid in the species ordination (Fig. 4).

Although Brunsfeld (1981) reported *Calamagrostis purpurascens* to be rare in his alpine study area, collections of the second author and others at ID document it as common, especially on calcareous substrates. Moseley (1985) reported one alpine community in which *Calamagrostis purpurascens* was dominant, but it was not an important component of the alpine communities studied by Caicco (1983).

Group 6: Carex rupestris (N = 17). The *Carex rupestris* community occupied the highest, driest, most exposed sites in the study area. Elevations ranged from 3011 to 3146 m with an exposure index of

3.9. All sites are likely blown snow-free in winter, and all have shallow, rocky soil derived from dolomite. The average slope was 16° but a great deal of variation exists between sites, some occurring on flat ridge tops, while others were on steep inclines. Overall, these communities are sparsely vegetated (35%); most of the area was exposed mineral soil. *Carex rupestris* accounted for 16% of the vegetation coverage, *Phlox pulvinata* 4%, with *Calamagrostis purpurascens* and *Cymopterus douglassii* minor components.

The plot ordination (Fig. 3) further emphasizes the relatively extreme habitat favored by this group, with the *Carex rupestris* plots occurring in the lower left quadrant indicating high exposure, high elevation, and a dolomite-derived soil. The species ordination (Fig. 4) shows *Carex rupestris* in a less extreme position, due to its presence in other communities, but *Cymopterus douglassii* maintains an outlier position. *Cymopterus douglassii* is a highly restricted endemic presently known only from the alpine of the Sheep Mountain RNA and a few alpine/subalpine sites in the vicinity of Mt. Borah, some 47 km southwest in the Lost River Range, Custer County, Idaho. It is only present in the community in the highest elevation sites, while *Calamagrostis purpurascens* becomes more important at lower elevations close to the ecotone between Groups 5 and 6.

Caicco (1983) found only one small example of this community in the Pioneer Mountains, and Moseley (1985) did not encounter it at all in east-central Idaho. This group appears to be rare in Idaho, but it was well-represented in our sampling.

Group 7: Dryas octopetala (N = 2). This community was represented by only two plots in one small area on rocky, dolomitic soil at an elevation of 3048 m. The site is characterized by a steep slope (26°), and a protected, low exposure, northeasterly aspect. The community occurred just below a ridgetop with persistent snowbanks 10 m upslope observed draining through the community (exposure index = 1.5). The vegetation cover was 65% with *Dryas octopetala* var. *hookeriana* accounting for 45%; other important species were *Lupinus argenteus* var. *depressus* (9%) and *Carex rupestris* (7%).

In the plot ordination (Fig. 3), Group 7 is located in the lower right quadrant, indicating a relatively low exposure, dolomite habitat preference. The same preference is evident in the species ordination (Fig. 4), with *Dryas octopetala* exceeded as an outlier by only two other species, *Salix nivalis* var. *nivalis* and *Zigadenus elegans*.

Brunsfeld (1981) collected *Dryas octopetala* in east-central Idaho, and described it as occasional, with a preference for rocky, calcareous substrates and protected, snow-covered ridges, but it was not reported either by Caicco (1983) or Moseley (1985).

Group 8: Leucopoa kingii (N = 6). By species composition, this group was recognized as unique by TWINSpan (Fig. 2) in the first division ($\lambda = 0.492$), with *Leucopoa kingii* communities being sep-

arated from the rest. A subsequent division further indicated two recognizable phases, a stable and an unstable phase, essentially as characterized by Moseley (1985).

The stable phase was found on a mesic, well-developed soil derived from quartzite with moderate slope (12°), an elevation of 3011 m, and a southwest aspect (exposure index = 2). Vegetation coverage was 70%, with *Leucopoa kingii* at 12%; other important species were *Carex elynoides* (34%) and *Lupinus argenteus* var. *depressus* (6%).

The unstable phase was present on a much drier, loose, rocky, dolomite substrate with a steep slope (27°), an elevation of 3036 m, and a west aspect (exposure index = 4). Vegetation coverage was 42%, with *Leucopoa kingii* at 22%; other important species were *Achillea millefolium* var. *alpicola* (4%) and *Cymopterus nivalis* (3%).

The plot ordination (Fig. 3) highlights the differences in the two phases in this group. The stable phase is in the upper right quadrant, revealing a low exposure, quartzite preference, while the unstable phase occupies the lower portion of the upper left quadrant, indicating a high exposure, dolomitic habitat.

Both phases are well-described in Moseley's (1985) investigation of the *Leucopoa kingii* communities of east-central Idaho. Caicco (1983) also observed a few, small *Leucopoa kingii* communities in the White Knob Mountains.

Environmental factors. The measured environmental variables were helpful in describing the community distributions, but did not distinguish between two communities, *Carex elynoides* and *Calamagrostis purpurascens*–*Carex elynoides*. An exposure gradient, determined by factors such as slope, aspect, snow accumulation/drainage patterns, and soil characteristics, was highly correlated with the first axis and accounted for the majority of the variation observed. Even though the study area has a limited elevation range, elevation was still correlated with both axes 1 and 2 and was helpful in interpreting community and species distributions. Substrate was strongly correlated with the second axis, and accounted for a substantial amount of the variation. Some communities were restricted to one substrate, while others were found on both dolomitic and quartzitic substrates. Caution must be used, however, in interpreting the community substrate preferences; the quartzite bands in the study area are in relatively protected, lower elevation depressions and so represent an environmental contrast to the immediately adjacent dolomite plots, independent of the substrate. Slope was also important, especially in the *Leucopoa kingii* community, and was correlated with the third axis.

Caicco (1983) also describes a "complex moisture-exposure gradient" in his ordinations of central Idaho alpine, as well as a "geographical" axis related to clusters of plots in his large study area. In east-central Idaho, Moseley (1985) again recognized a moisture-

exposure gradient as important. In addition, he identified species composition changes with changes in substrate (limestone vs. non-limestone) and soil stability.

That exposure was found to be important in the distribution of Idaho alpine is no surprise. Billings (1973) clearly describes a "mesotopographic gradient" that explains all the exposure factors found in our study, e.g., slope, aspect, snow accumulation, and drainage. More recently, Isard (1986) thoroughly investigated topographical environmental influences on Niwot Ridge, Colorado, and again, vegetation distribution was found to be dependent on snow accumulation and drainage patterns.

East-central Idaho supports a well-developed, recognizable alpine vegetation. The present study focused on one such alpine site and found eight distinctive communities described on the basis of habitat preference. An exposure gradient was found to be most highly correlated with the observed variation in habitat preferences, but elevation, substrate, and slope were also important. In general, the study area communities present a uniformly dry turf-like physiognomy, with some early snowbed and *Dryas* or *Salix* mat communities occasionally present. This is in sharp contrast to the other regional alpine studies, where fellfields and meadows are also common. Winds, topography, and precipitation patterns appear to be creating a relatively dry alpine habitat; substantial drought stress was obvious at the completion of sampling on 25 July. Drought conditions may help explain the absence of wet meadows, but not the lack of fellfields dominated by cushion plants. These unique features warrant further investigation.

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LITERATURE CITED

- BILLINGS, W. D. 1973. Arctic and alpine vegetations: similarities, differences, and susceptibility to disturbance. *Bioscience* 23:697-704.
- BLISS, L. C. 1963. Alpine plant communities of the Presidential Range, New Hampshire. *Ecology* 44:678-697.
- BRUNSFELD, S. J. 1981. Alpine flora of east-central Idaho. M.S. thesis. Univ. Idaho, Moscow. 205 pp.
- CAICCO, S. L. 1983. Alpine vegetation of the Copper Basin Area, south-central Idaho. M.S. thesis. Univ. Idaho, Moscow. 99 pp.
- DAUBENMIRE, R. 1959. A canopy-coverage method of vegetational analysis. *North-west Science* 33:43-64.

- DEL MORAL, R. 1979. High-elevation species clusters in the Enchantment Lakes Basin, Washington. *Madroño* 26:164–172.
- DOUGLAS, G. W. and L. C. BLISS. 1977. Alpine and high subalpine plant communities of the north Cascades Range, Washington and British Columbia. *Ecological Monographs* 47:113–150.
- GAUCH, H. G., JR. 1982. *Multivariate analysis in community ecology*. Cambridge University Press, New York, NY. 298 pp.
- HARTMAN, R. L. and L. CONSTANCE. 1985. Two new species of *Cymopterus* (Umbelliferae) from Western North America. *Brittonia* 37:88–95.
- HENDERSON, D. M. 1978. Notes on the Flora of east-central Idaho. *Madroño* 25: 172–174.
- . 1992. Flora of east central Idaho: the project. *Journal of the Idaho Academy of Science* 28:75–81.
- HILL, M. O. 1979. TWINSpan—a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, NY. 60 pp.
- ISARD, S. A. 1986. Factors influencing soil moisture and plant community distribution on Niwot Ridge, Front Range, Colorado, U.S.A. *Arctic and Alpine Research* 18:83–96.
- McKELVEY, S. D. 1955. Botanical exploration of the trans-Mississippi west, 1790–1850. Arnold Arboretum of Harvard University, Jamaica Plains, MA. 1144 pp.
- MOSELEY, R. K. 1985. Synecological relationships of alpine spike-fescue grasslands in east-central Idaho. M.S. thesis. Univ. Idaho, Moscow. 70 pp.
- ROSS, S. H. and C. N. SAVAGE. 1967. Idaho earth science: geology, fossils, climate, water, and soils. Idaho Bureau of Mines and Geology, Moscow. 271 pp.
- RUPPEL, E. T. and D. A. LOPEZ. 1981. Geologic map of the Gilmore Quadrangle, Lemhi and Custer Counties, Idaho. GQ-1543. U.S. Geological Survey, Denver, CO.
- TER BRAAK, C. J. F. 1987. Ordination. Pp. 91–173 in R. H. Jongman, C. J. F. Ter Braak, and O. F. R. Van Tongeren (eds.), *Data analysis in community and landscape ecology*. Pudoc, Wageningen, the Netherlands. 299 pp.
- . 1987–1992. CANOCO—a FORTRAN program for canonical community ordination. Microcomputer Power, Ithaca, NY. 130 pp.
- WELSH, S. L., N. D. ATWOOD, L. C. HIGGINS, and S. GOODRICH. 1987. A Utah Flora. Great Basin Naturalist Memoirs number 9. Brigham Young University Press, Provo, UT. 894 pp.

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